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(54) LIGHTWEIGHT CELLULAR CONCRETE PANEL AND METHOD OF MAKING THE SAME

(71) We, PITTSBURGH CORNING CORPORATION, a Corporation organised and existing according to the laws of the Commonwealth of Pennsylvania, United States of America, of One Gateway Center, Pittsburgh, Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a lightweight cellular concrete panel.

To prevent fire from spreading in multi-storey buildings, each floor is isolated from vertical air shafts such as elevator shafts and stairwells by fireproof doors. The doors are kept closed and are intended to serve as fire barriers and prevent the fire from spreading to upper floors through the elevator shafts and stairwells. The fireproof doors are fabricated with outer laminates or skins encapsulating a core panel of fire resistant material. The core panel is intended to provide rigidity for the door and has fire resistant properties.

Conventional core panels are fabricated from slabs of hydrous calcium silicate that is cast to the desired thickness by pouring a slurry of the silicate and asbestos fibers into a tray and removing the water and jelling the slurry in an autoclave. The slab contains micropores that provide the insulating properties and has a density of about 17 pounds per cubic foot. The slabs are formed in sizes ranging up to 18 inches by 36 inches and are tongued or grooved along all edges. A plurality of the slabs are bonded to an outer skin in edgewise abutting relation to form a core for a door with dimensions of about 7 feet by 3 feet. The fabrication of the panels and doors is both time consuming and expensive. There is a need for a strong lightweight fire resistant panel that may be easily and inexpensively fabricated.

According to the present invention we provide a lightweight cellular concrete panel comprising an aggregate of reinforcing fibres and multicellular glass nodules bound in a cellular matrix of cement, said reinforcing fibres being present in an amount of from 0.5 to 25.0 parts by weight per 100 parts by weight of cement, on a dry basis.

The panel has utility as a core for doors, wall panels and the like. The cellular glass nodules are preferably spherical in shape with a diameter of between 1/8 inch and 1/4 inch.

Also according to the invention we provide a process for the manufacture of such a panel which comprises forming a mixture containing the fibrous and nodular aggregates, the cement, an air entraining agent and sufficient water to form a workable mixture, casting the mixture in an elongated mould, allowing the mixture to cure in said mould sufficiently to form a partially cured, self-supporting, fibre-reinforced cellular concrete billet, removing the partially cured billet from the mould, and slicing the billet into a plurality of panels whilst still in the partially cured state.

Throughout this specification, the term "cement" is intended to designate cementitious materials having as active constituents magnesium or calcium derivatives, an example of which is the commercially available Portland cement. For ordinary structural use, conventional Portland cement generally designated Type I (General Purpose) or Type III (High Early Strength) Portland cement may be used. Type III Portland cement is preferred.

Air entraining agents are used to produce the cellular matrix of cement by entraining air in the cement during mixing and retaining the air within the cement as it sets so that the cement contains cells or voids of the entrapped air. Suitable air entraining agents are Vinsol, Darex, lignin-sulphonic acid and licorice root residues, which are well known. Other suitable air entraining agents may also be employed. The preferred air entraining agent is sold under the trademark Vinsol and is a saponified resin extract from southern pine wood. A retarding densifier may also be included in the

mixture. A suitable water reducing retarder is sold by Sika Chemical Company, Passaic, New Jersey, under the trademark Plastiment and is a derivative of a hydroxylated carboxylated carboxylic acid that controls the rate of cement hydration by retarding and reducing the cement gel.

The multicellular glass nodules which serve as an aggregate in the lightweight cellular concrete panels of the present invention preferably have a continuous outer skin or surface which is impervious to moisture and hydrophilic to the extent that the nodules are wetted by the cement paste and the cement, upon curing, bonds to the surface of the nodule.

The multicellular glass nodules may be prepared according to U.S. patent No. 3,354,024 from a pulverulent silica-lime glass and a carbonaceous cellulating agent. The cellular nodules are preferably prepared according to the method of U.S. patent No. 3,354,024 wherein the pellet of uncellulated material contains a fluxing agent dispersed therein adjacent the outer surface. The parting agent employed during the cellulating process in a rotary kiln is preferably a compound which forms a glassy material, such as Al_2O_3. During the cellulation process a portion of the glass former is dissolved in the fluxing agent on the surface of the nodule to provide an outer continuous skin of chemically durable glass that has a different composition than the core of the cellular glass nodule. The high alumina glass surface provides a nodule that is more chemically durable in the presence of cement than other conventional glasses.

The multicellular glass nodules may be formed with different densities and different sizes. It is preferred for the present invention to use spherical cellular glass nodules having actual densities of between 10 and 25 pounds per cubic foot and a bulk density of between 7 and 10 pounds per cubic foot. It should be understood, however, that cellular inorganic nodules of other densities may be used to form lightweight cellular concrete panels according to the invention. The density of the panels is preferably from 25 to 38.5 lgs per cu. ft. The flex strength is preferably from 60—416.7 lbs per sq. inch.

The reinforcing fibers may be any suitable fibers that reinforce the cellular concrete and improve its handleability, especially when the concrete is partially set or cured. Asbestos, nylon, metal and sisal fibers have been found suitable. The sisal fibers, however, are preferred in lengths of between 1.00 and 2 inches. The sistal fibers disperse and are uniformly distributed in the concrete admixture. The nonmetallic reinforcing fiber-cement ratio is advantageously between 0.5 to 2.0 parts by weight fibers per 100 parts by weight cement. The water to cement ratio on a weight basis depends primarily on the workability of the admixture. It is desired that only sufficient water be utilized to achieve the desired fluidity of the admixture for pouring and forming the billets in the mold. The volumetric ratio of aggregates to dry cement in the range of between about 3 to 7 parts, preferably 4 parts, of cellular glass nodule aggregates for each part of cement have been found suitable. The following examples will illustrate the invention further.

Example I

1,370 grams of cellular glass nodules having a bulk density of about 8 pounds per cubic foot and 18.9 grams of nylon fibers were premixed with 1,950 grams of water, 2.5 grams of Plastiment and 35.0 grams of Vinsol for approximately 30 seconds. 3,550 grams of Type III (Early Strength) cement was added to the slurry of wet fibers and nodules and was mixed for a period of 1.5 minutes. The nylon fibers were approximately 0.5 inches long, 6.0 denier Type 120. After mixing for approximately 1-1/2 minutes, the mixture was poured into a mold and cured for 13 days. The cellular concrete reinforced with nylon fibers had the following properties.

Density	30.46 p.s.i.
Compressive Strength	460.0 p.s.i.
Tensile Strength	38.0 p.s.i.
Flex Strength	101.0 p.s.i.

Example II

1,370.0 grams of nodules were admixed with 37 grams of the same type of nylon fiber as Example I, 1,950 grams of water, 2.5 ml. of Plastiment and 35 ml. of Vinsol for approximately 30 second and 3,555 grams of Type III Portland cement was added to the admixture and mixed for approximately 1.5 minutes. The admixture was poured into a mold and had an end product volume which was approximately 125% of the volume of the basic constituents. After 13 days the physical properties of the cured slab were as follows.

Density	28.56 p.s.i.
Compressive Strength	500.0 p.s.i.
Tensile Strength	39.0 p.s.i.
Flex Strength	113.0 p.s.i.

Example III

3,555 grams of cement and 50 grams of asbestos fiber were admixed with 2,450 grams of water, 2.5 ml. Plastiment and 35 ml. Vinsol for a period of 1 minute. 1,395 grams of nodules were added to the cement slurry and mixed for an additional minute. The end product volume was 127% of the volume of the basic constituents. The asbestos fibers were Bell grade 3Z—700 sold by Nicolet Industries, Inc. The admixture was poured into a mold and permitted to cure for 14 days and

had the following properties after that time.

Density	27.0 p.c.f.
Compressive Strength	342.0 p.s.i.
Tensile Strength	25.6 p.s.i.
Flex Strength	91.6 p.s.i.

Example IV

1,375 grams of nodules and 50 grams of the same type of asbestos fibers as used in Example III were premixed with 2,500 grams of water and 2.5 ml. Plastiment and 35 ml. Vinsol for a period of 30 seconds. 3,355 grams of cement was added to the premix and mixed therewith for a period of approximately 1.5 minutes and was thereafter poured into a mold. An end product volume which was 125% of the volume of the basic constituents was obtained. After 14 days the cellular concrete had the following physical properties.

Density	27.3 p.c.f.
Compressive Strength	447.0 p.s.i.
Tensile Strength	27.3 p.s.i.
Flex Strength	105.7 p.s.i.

Example V

1,345 grams of cellular glass nodules and 38.0 grams of sisal fibers having a length of approximately 2 inches were premixed with 1,950 grams of water, 2.5 ml. Plastiment, 35.0 ml. Vinsol for a period of 30 seconds. Thereafter 3,555 grams of cement were added to the premix and admixed therewith for 1.5 minutes. The admixture was poured into a mold and cured for a period of 14 days and after that period had the following properties.

Density	27.6 p.c.f.
Compressive Strength	493.0 p.s.i.
Tensile Strength	29.9 p.s.i.
Flex Strength	102.4 p.s.i.

It should be noted the improved tensile strength obtained when the cement and sisal fibers are first premixed with the liquid and the nodules added thereto as illustrated in Example V.

Example VI

A commercial size billet was prepared by admixing 4 cubic feet of nodules having a bulk density of about 8 pounds per cubic foot with 53.0 pounds of water, 25 ml. of Plastiment and 1 pint Vinsol and 1 pound of sisal fibers for a period of approximately 1 minute. The sisal fibers were added to the admixture while the nodules and the liquid were being mixed. 94 pounds of Type III cement was added to the wet premix and was mixed for a period of approximately 1.5 minutes. Thereafter, the admixture was poured into a mold and cured for a period of 10 days. The billet had the following properties after that period of time.

Density	31.0 p.c.f.
Compressive Strength	539.0 p.s.i.
Tensile Strength	29.5 p.s.i.
Flex Strength	78.4 p.s.i.

Example VII

4,265 grams of nodules, 10,665 grams of Type III Portland cement, 2,632 grams of steel fibers, 5,250 grams of water, 15 ml. Plastiment and 120 ml. of Vinsol were mixed in a conventional concrete mixer. The admixture was vibrated in the mold with the steel fibers falling into an orientation parallel to the horizontal plane. The admixture had the following properties after 14 days of curing.

Density	38.5 p.c.f.
Compressive Strength	593.0 p.s.i.
Flex Strength	416.7 p.s.i.

The following table illustrates the physical properties of the cellular reinforced concrete admixtures of Examples I—VII. The volume ratio represents the volumetric ratio of aggregates to cement in the mixtures and the fiber-cement ratio represents the parts by weight of the fiber for each hundred parts by weight of cement and is approximate.

TABLE I

Example	Nodules:Cement Volume Ratio	Fiber Type	Fiber/ Cement Ratio*	Volume of product based on volume of basic consituents	Days Cure	Density p.c.f.	Compressive Strength p.s.i.	Tensile Strength p.s.i.	Flex Strength p.s.i.
I	4:1	Nylon	0.5	118.5	13	30.46	460.0	38.0	101.0
II	4:1	Nylon	1.0	125.0	13	28.56	500.0	39.0	113.0
III	4:1	Asbestos	1.5	127.0	14	27.0	342.0	25.6	91.6
IV	4:1	Asbestos	1.5	125.0	14	27.3	447.0	27.3	105.7
V	4:1	Sisal	1.0	131.0	14	27.6	493.0	29.9	102.4
VI	4:1	Sisal	1.06	—	10	31.0	539.0	29.5	78.4
VII	4:1	Steel	24.7	—	14	38.5	593.0	—	416.7

*Fiber parts by weight per 100 parts cement (dry basis)

One process for making the reinforced cellular concrete core panels for doors includes preparing an admixture similar to Example VI and filling a mold, preferably a mold 4 feet long, 8 feet wide and 12 inches deep. The cellular concrete admixture is permitted to cure for a period of about 18 hours and the mold side boards are removed to expose the shaped billet of cellular reinforced concrete. After 18 hours, the billet retains its shape and does not slump or distort when the mold side boards are removed. Slabs are then cut or sliced from the billet with a conventional band saw.

The slabs or panels have a thickness of between 1-1/8 inch nominal and 1-5/8 inch nominal. After the panels are cut from the billet, they are transported manually to another location for further curing. The billet, 18 hours after pouring, has attained sufficient rigidity to permit the billet to be cut into relatively thin panels without subjecting the saw blade to excessive wear. When the billets are permitted to cure for longer periods, as for example, 28 days and are then cut into panels, the saw blade wear is excessive and a carbon steel blade is worn to the extent that a single blade cannot effectively cut one billet. After 18 hours of curing, the cellular glass nodule aggregates are sufficiently bonded to the cement paste matrix that the saw blade in cutting through the billet cuts through the cellular glass nodules so that flat surfaces of the cut nodules are present on the surface of the panels and the panels have a planar surface.

The building industry has prepared minimum standards for acceptable core material.

According to one of these standards the minimum compressive strength is 150 pounds per square inch, the minimum tensile strength is 20 pounds per square inch and the minimum flex strength is 50 pounds per square inch. The compressive strength of the cellular reinforced concrete disclosed in the examples ranges between about 342 pounds per square inch and strength of the cellular reinforced concrete ranges between 25.6 pounds per square inch and 39 pounds per square inch. The measured flex strength with the nonmetallic reinforcing fibers ranges between 78.4 pounds per square inch and 113.0 pounds per square inch so that the herein disclosed cellular reinforced concrete panels are well above the minimum acceptable standards set out above.

WHAT WE CLAIM IS:—

1. A lightweight cellular concrete panel comprising an aggregate of reinforcing fibres and multicellular glass nodules bound in a cellular matrix of cement, said reinforcing fibres being present in an amount of from 0.5 to 25.0 parts by weight per 100 parts by weight of cement, on a dry basis.

2. A panel according to claim 1, having a density of from 25 to 38.5 lbs. per cu. ft.

3. A panel according to claim 1 or 2, having a flex strength of from 60—416.7 lbs per sq. inch.

4. A panel according to any one of the preceding claims, wherein the volumetric ratio of multicellular nodules to cement, on a dry basis, is in the range 3:1 to 7:1.

5. A panel according to claim 4, wherein said ratio is about 4:1.

6. A panel according to any one of the preceding claims, wherein said multicellular nodules are spherical in shape and have a diameter of from 1/8—1/4 inch.

7. A panel according to any one of the preceding claims, wherein the glass nodules have an actual density of from 10—25 lbs. per cu. ft. and a bulk density of from 7—10 lbs. cu. ft.

8. A panel according to any one of the preceding claims, wherein the reinforcing fibers are of a non-metallic material.

9. A panel according to claim 8, wherein said fibers are of asbestos, nylon or sisal.

10. A panel according to claim 8, wherein said fibers are sisal fibers having a length of from 1-2 inches.

11. A panel according to any one of claims 8—10, wherein the fibers are present in an amount of from 0.5 to 2.0 parts by weight per 100 parts by weight of cement on a dry basis.

12. A panel according to any one of the preceding claims, having a thickness of from 1 1/8—1 5/8 inches.

13. A panel according to any one of the preceding claims, which is rectangular in shape.

14. A door or wall panel having a cored structure, wherein the core is constituted by a concrete panel according to any one of the preceding claims.

15. A panel according to claim 1, substantially as hereinbefore described in any one of the foregoing Examples.

16. A process for the manufacture of a concrete panel according to any one of claims 1—13, which comprises forming a mixture containing the fibrous and nodular aggregates, the cement, an air entraining agent and sufficient water to form a workable mixture, casting the mixture in an elongated mould, allowing the mixture to cure in said mould sufficiently to form a partially cured, self-supporting, fibre-reinforced cellular concrete billet, removing the partially cured billet from the mould, and slicing the billet into a plurality of panels whilst still in the partially cured state, and thereafter allowing the sliced panel to complete the cure.

17. A process according to claim 16, wherein the mixture is allowed to cure in said mold for about 18 hours before slicing to form said panels.

18. Concrete panels according to any one of claims 1—13, when made by the process of claim 16 or 17.

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